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ON THE ORIGIN OF THE GALAPAGOS ISLANDS.

BY G. BAUR.

ALL islands can be divided into two principal groups. 1. Islands developed from continents or larger bodies of land through isolation or subsidence: *continental islands.* 2. Islands not developed from continents, but from submarine portions of the earth: *oceanic islands.* The flora and fauna of the first group will be more or less *harmonic,*—that is to say, the islands will be like satellites of the continent from which they developed, and the whole group comparable to a planetary system. The flora and fauna of the second group will be *disharmonic,*—that is to say, it will be composed of a mixture of forms which have been introduced accidentally from other places. It is evident that the first group of islands will be affected in the same way; there will be immigrants from other localities besides the original inhabitants. *Continental islands, therefore, may be composed of two floral and faunal elements: first, an original (endogenous) one; and second a secondary (exogenous) one. Oceanic islands, however, will only contain a secondary (or exogenous) floral and faunal element.*

We will now proceed to examine whether the Galapagos belong to the first or second group of islands; whether they are detached portions of a continent, or of new origin emerged from the sea. These islands, better than any other group, afford a splendid opportunity for the examination of this question. They had never been inhabited before their discovery by the Spaniards in the sixteenth century. Buccaneers and whalers made the islands a place of frequent resort; but it was not before 1832 that a small colony was established on Charles Island, which, however, was soon abandoned again. To-day a small settlement is found on Chatham Island only, under the management of Señor Manuel Cobos. The only animals which seem to have been seriously affected by these intruders are the tortoises, which had once been so very numerous on all the islands. On some of them at least—Charles Island, for instance—they are extirpated; but it is probable that a few specimens still exist on some other islands on which they are now considered to be exterminated. All the islands, with the probable exception of Charles and Chatham, show with little doubt nearly the original condition.

The Galapagos are situated on the equator, about 600 miles west from the coast of Ecuador, to which state they politically belong. They are placed between the 89th and 92d degree west of Greenwich, covering about three degrees of longitude, and extending on each side of the equator one-and-a-half degrees north and south. (The best map published is No. 1375 of the British Admiralty, based principally on the researches of Captain Fitzroy, of the historical "Beagle.") There are five principal islands, eleven smaller ones, and a great number of islets and rocks. The five principal ones are situated between the equator and the 1° south. They are Narborough, Albemarle, James, Indefatigable, Chatham. Of the eleven smaller islands three are in the same region, Jervis, Duncan, Barrington; three are between the 1° and 2° south, Brattle, Charles, Hood; and five north between the equator and the 2° north, Tower, Bindloe, Abingdon, Wenman, Culpepper. Hood is the most southern, 1° 27′ South; Culpepper the most northern and also the most western island, 1° 39′ north, 92° west; Chatham is the most eastern, 89° 17′ west. Albemarle is by far the largest; it is the only one cut by the equator, and is about 140 km. long. Then follow Indefatigable, Narborough, James, Chatham, Charles, Bindloe, Abingdon, Barrington, Tower, Duncan, Jervis, Brattle; the last only about 1½ km. long and 1 km. broad. As is well known, the whole group is volcanic. The highest mountain, on the southwest end of Albemarle, is 1570 m. high. The elevation of the other islands varies from 70 m. (Tower) to 1270 m. (Narborough). Albemarle, and especially Narborough, the most western island of the larger ones, have frequently been in a state of eruption. Delano speaks of one on Albemarle in 1797 and 1800, Porter in 1813, and Morrell witnessed a most terrific outbreak on Narborough in 1825. Fitzroy saw smoke on a southeastern volcano on Albemarle in 1835. Since that time these volcanoes seem to have been in a state of inactivity. Wolf, who visited the islands in

1875, states that Narborough still has an active central crater of enormous size. Most of the islands consist of basaltic rocks and masses of scoriæ and lava, but besides we find, according to Wolf, remains of an older volcanic formation on Charles Island and the small islands Gardner, Caldwell, and Enderby, which surround it. Dr. Th. Wolf, the state geologist of Ecuador, visited the islands twice, according to a letter received from him. He spent in all six months on the group,—more time than any other visitor, Dr. Habel excepted. He published a small pamphlet about the islands in 1879 (Ein Besuch der Galapagos-Inseln. Heidelberg, 1879, 44 pp., 3 maps). The following account about the climate is taken principally from him and from "The South American Pilot."

The climate, considering that these islands are directly on the equator, is far from being excessively hot, a circumstance which is chiefly owing to the singularly low temperature of the surrounding sea, which is 23° C. On Charles Island at an elevation of 140 m. the thermometer was 19–21° (about 68° F.), and at about 300 m. 18–19°. Darwin observed a heat of 34° C. (93° F.) in his tent when the thermometer stood at 29° C. in the wind and sun, but which, when plunged in the soil, rose at once to 58° C., and would probably have risen higher had the tube been longer.

The rainy season is between February and June, but is very irregular, generally very short, and often it stops entirely for one or two years. In the higher portions of the islands, about 270 m., there is often rain all the year, but very little. In August and October Wolf observed such squalls, so-called "garruas," very often. They repeated each other often five or six times in a day, but never lasted more than half an hour. They are confined to the high plateau. The whole broad lower zone up to 170 m. is nearly without any rain; therefore the upper region remains always green, the lower one arid and barren. On the southeastern parts of the islands, on the side of the southern trade-winds, the damp region extends nearly 70 m. more down than on the northern side. It is evident that the conditions of the vegetation are dependent upon this different distribution of humidity. Near the border of the sea we find different maritime plants; in some of the bays mangroves and avicenias. In ascending the hills from the shore the whole ground in all directions is covered with apparently withered brushes; but on a closer examination it is found that these plants are mostly in bloom. The most common brush in this region is a Lantana, one of the Verbenaceæ, and members of the Euphorbiaceæ, Croton for instance. This brushwood grows up to a height of 5 feet or 6 feet, rarely 10 feet, and here and there are found Algoraba trees about 20 feet high, and also sporadic Palo Santos (Guaiacum). The latter is the largest tree in the lower region; it reaches a height of 30 feet, and 3 feet in circumference. On places which do not allow the growth of any other plant, the grotesque, tree-like Opuntias and gigantic Cereus are found.

The Cereus is generally seen in the most barren spots. These forms give a very characteristic appearance to this region. The Opuntia reaches a height of 20 feet, and a thickness of two feet; the Cereus the same proportions. Besides these characteristic plants are found Gramineæ, Cyperaceæ, Euphorbiaceæ, Labiatæ, Compositæ, and so on (about fifty to sixty species according to Wolf). There are only a few Cryptogamia, the most important of which is the Orchilla (*Rocella tinctoria*), which is found not higher than 100 m. This is the condition of the vegetation up to 200 m. Now other shrubbery, especially Compositæ, appears; the Algoraba and Palo Santo are of stronger growth; the Lantanas and Cactaceæ disappear. The ground is still more covered with brushwood of the withered aspect. A white Usnea, which hangs in long strings from the trees, alone indicates a little more humidity. This plant is characteristic of a zone between 200 m. to 270 m., separating the dry and humid region. It is easily distinguished from a far distance by its white color.

When the high plateau between 270 m. to 300 m. is reached, the whole scenery changes. A refreshing, moist breeze comes from the coast; the traveler is surrounded by green woods and stands on meadows. These woods are principally composed of about thirty-feet-high trees, of the Sanguisorbaceæ and Compositæ, of an Andean type. Herr Wolf remarks: Everybody who knows the flora of Ecuador must be reminded of the mountains of the

Andes, and he appears to be on an elevation of about 3,000 m.; but in fact he is only 300 m. high. Wolf found great resemblance with the small Paramo forests of the Andes, not only in the habitus of the trees, but also in the small plants which cover the ground and in the mosses and lichens which cover the trees. The woods are free, without creeping plants, making a passage easy. They are interrupted by small meadows, consisting nearly entirely of small Gramineæ and Cyperaceæ. Above this woody region another one could be distinguished, which is free from trees, and only covered with short grass.

The description of these different zones is based on the condition found on Charles Island; but it is the same, according to Wolf, on the others of high elevation. From this it is evident that different islands which do not reach to the humid region, like Hood, Barrington, Tower, and so on, show only the arid state.

After this description of the climatological condition of the islands, I have to make some remarks on the topography of the whole group. The deepest sounding on record is 671 fathoms, between Tower and Indefatigable Islands; between the median islands the greatest depth does not surpass 300 fathoms; but a complete series of soundings between the different islands may bring to light quite different results. There is little doubt, however, that all the islands, Culpepper and Wenman perhaps excepted, are placed within the 1000-fathoms line. Northeast of Chatham, 0° 24′ south, 80° 6′ west, 812 fathoms are recorded by the "Albatross." It is probable that an elevation of 300 fathoms or 550 m. would bring all the central islands together.[1]

I give now the approximate distances between some of the islands: Hood to Culpepper, 430 km.; Chatham to Narborough, 262 km.; Hood to Chatham, 50 km.; Hood to Charles, 64 km.; Chatham to Indefatigable, 65 km.; Albemarle to Abingdon, 77 km.; Abingdon to Bindloe, 23 km.; Bindloe to Tower, 50 km.; Abingdon to Wenman, 141 km.; Wenman to Culpepper,

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[1] The soundings of the "Albatross" have shown that the Galapagos are connected through Cocos and Malpelo Islands with Central America by the 4000-m. line. This is an important fact; all the older maps showed the Galapagos separated from Central America.

36 km.; Duncan to Indefatigable, 10 km.; Jervis to James, 8 km.; Barrington to Indefatigable, 18 km.; Indefatigable to James, 19 km.; James to Albemarle, 18 km.; Charles to Indefatigable, 50 km.

Currents.—From the "South American Pilot" I record: "The currents about these islands are remarkable, for, in addition to their velocity, which is from one to two-and-a-half miles an hour, and usually towards the west and northwest, there is a surprising difference in temperature of the bodies of water moving within a few miles from each other. These striking differences are owing to the cool current coming from the southward along the coasts of Chili and Peru, which at the Galapagos encounters a far warmer body of water coming from the Bay of Panama. Heavy rollers occasionally break upon the northern shores during the rainy season, though no wind of any consequence accompanies them. They are probably caused by the northers from Tehuantepec, and the Papagayos or northeast winds, which are so well known on the coast between Panama and Acapulco." In the vicinity of the islands calms prevail from January to April; from the middle of April to the end of December the trade-wind blows with regularity, and gales are unknown.

After these necessary remarks we can proceed to examine the fauna and flora.

1. *The Fauna.*—I shall restrict myself to the higher vertebrates, of which I shall give what is known. The only mammals which have been recorded are a mouse, two species of seals, and bats. The mouse is of the American genus Hesperomys. Darwin found it on Chatham, and Wolf saw a skin of it on Barrington Island. Further researches must decide whether this form is introduced or not. The fact that Wolf found it on the deserted Barrington speaks for its being indigenous. The seals found on the islands are *Otaria jubata* and *Arctocephalus australis.* They are still numerous, but in former times must have been exceedingly abundant, as I conclude from the work of Morrell. These two seals belong to Antarctic forms, and show in the Galapagos their most northern extension. It is quite probable that they represent species distinct from the more southern forms. So far as I know,

only the skeletons have been studied (Allen, " Pinnipedia "). Bats have been seen by Habel, and are also mentioned by Wolf; but no specimens have been collected so far.

Before speaking about the birds, I shall treat the reptiles, which are represented by tortoises, lizards, and snakes. The gigantic land tortoises always have attracted attention. The Spaniards gave the name Galapagos to these islands, which means tortoise. I may mention here that the etymology of the word Galapago is not known; the regular Spanish word for tortoise is tortuga, as in the Portuguese. The Portuguese also have the word cacado, which is of South American origin. It is probable that the word Galapago is of Central or South American origin also. I have treated on the tortoises in a paper published lately in the AMERICAN NATURALIST, and I shall give my results here in brief.

It was David Porter, the well-known American commodore of the " Essex," who pointed out for the first time the important fact that the different islands contain different races of the tortoise. Darwin has fully supported this view. He states that the inhabitants of Charles Island could tell from the aspect of the tortoise from which particular island it came. Tortoises have been recorded from Hood, Charles, Chatham, Indefatigable, Duncan, James, Albemarle, Abingdon. Nothing is known in this regard about Barrington, Brattle, Jervis, Bindloe, Tower, and the others. So far we know, there are six races of land tortoises from these islands: 1. *T. elephantopus* Harlan = *T. vicina*, Guenther; from South Albemarle. 2. *T. galapagoënsis* Baur = *T. elephantopus* Jackson; from Charles Island. The only complete specimen is in the Museum of the Boston Society of Natural History. 3. *T. abingdonii* Guenther = *T. ephippium* Guenther; Abingdon Island. 4. *T. microphyes* Guenth.; North Albemarle. 5. *T. guentheri* Baur = *T. elephantopus* Guenther; locality unknown. 6. *T. nigrita* Dum. and Bib.; locality unknown.

It is impossible yet to determine to which island the two last tortoises belong; but the important fact remains that the tortoises are different on the different islands. The species from Abingdon Island, for instance, is not found on any other one; the Charles Island form is only found there, and so on.

The genus Tropidurus of the Iguanidæ shows better than any other form the peculiar specialization on the different islands. I have already in a former paper spoken about the variation of this lizard. I reached the following result:

1. *Each island has only a single variety or species of Tropidurus.*
2. *Nearly every island has a peculiar variety or species of Tropidurus.*

These results were based on 128 specimens of Tropidurus collected by the "Albatross" on eight islands, namely: Chatham, Hood, Gardner (a little islet northeast of Hood), North Albemarle (Tagus Cove), James, Duncan, Indefatigable, Abingdon.

The first species of Tropidurus described from the Galapagos was *T. grayii* Bell, the type specimens of which had been collected by Darwin on Charles and Chatham Islands. I have taken the form from Charles Island, of which the "Albatross" did not get any specimens as the type of *Tropidurus grayii*, because Chatham Island is inhabited by a distinct form, which has been described as *T. lemniscatus* by Prof. Cope. Specimens from Indefatigable and James Islands are very much alike, and probably different from the specimens from Charles Island. I named these *T. indefatigabilis*. The peculiar form from Duncan Island was called *T. duncanensis*; that from Hood and Gardner Islands *T. delanonis*; the Albemarle form *T. albemarlensis*; that from Abingdon *T. abingdonii*; the Bindloe forms were considered as typical for *T. pacificus* Steind. No conclusion could be reached in regard to *T. bivittatus* Peters and *T. pacificus* (var. *habeli*) Steind., the localities of these forms not being known.

The following table shows the number of scales round the middle of the body in the different forms: *Tropidurus indefatigabilis* Baur, 55–59; *Tropidurus lemniscatus* Cope, 55–61; *Tropidurus albemarlensis* Baur, 57–63; *Tropidurus grayii* Bell, 55–65; *Tropidurus duncanensis* Baur, 72–79; *Tropidurus delanonis* Baur, 82-85; *Tropidurus pacificus* Steind., 85-90; *Tropidurus abingdonii* Baur, 95–101.

The specimens from Jervis figured by Steindachner as *T. grayii* are probably identical or closely related to *T. indefatigabilis*. Nothing is known of these lizards from Brattle, Barrington, Tower, Wenman, Culpepper, Narborough. I do not doubt that on most of these islands we will find other species of Tropidurus. It would be of special interest to know whether any of them are found on Narborough, since we have to suppose that probably every organism was killed by that great eruption mentioned by Morrell. No other animal or plant shows the specialization of a single genus in the different islands so well as Tropidurus. On every or nearly every island it has developed into a different race or species. Let us now, for instance, compare the forms from Gardner and Duncan Islands with those from the nearest islands. On Gardner Island we find the same species as on Hood Island. Gardner is only one kilometer distant from Hood. The water between the two is not deep, not exceeding five fathoms. Between these islands are placed four smaller islets and the Magicienne Rock (Brit. Adm. Chart, 1376).

The species from Duncan Island is totally different from that of Indefatigable. The islands are only ten km. distant from each other. The deepest sounding taken between the two is, however, 60 fathoms. No specimen of *T. duncanensis* occurs on the very near Indefatigable, and none of *T. indefatigabilis* on Duncan. The races from the distant Abingdon and Bindloe and the low Hood Islands are more different from the central forms than those among each other.

Besides the genus Tropidurus, which is only found in South America, we have two other genera of Iguanidæ which are peculiar to the islands: the land and sea guanas, as called since the times of Dampier: Conolophus and Amblyrhynchus, the latter reaching a length of nearly four feet.

Amblyrhynchus is the only "oceanic" form of the Iguanidæ. It lives upon sea-weeds, and to get them it goes out to the sea, but never far from the shore. It is probably found on all islands. The "Albatross" collected specimens on Abingdon, Duncan, Hood, Gardner, James, Chatham, and it has been recorded from other islands, Charles, Barrington, Jervis, Albemarle, by Darwin, Steindachner, Wolf, and others. The individuals of the different islands have never been studied carefully; but I do not doubt that even here we find modifications according to islands. Perhaps the thirteen specimens brought back by the "Albatross" could give some light when closely examined. Darwin already mentions differences. According to Steindachner, only small specimens are found on Jervis Island. Wolf found the specimens from Barrington different from those from Charles; they were all smaller and the dorsal spines were not so much developed. There is, therefore, evidence that even these semi-aquatic animals show some modification on the different islands.

Conolophus.—This large land form, no specimens of which were collected by the "Albatross," is so far only recorded from Albemarle, Indefatigable, Barrington, and James. Porter already states that it is absent from Charles. Nothing is known about the variation of this lizard, few specimens only having been collected. The Geckonidæ are represented by the genus Phyllodactylus. Charles Island contains a peculiar form, *Ph. galapagoënsis* Peters, of which the "Albatross" got one specimen. Two other species are recorded by Prof. Cope from Chatham, *Ph. tuberculosus* Wiegm., and *Phyllodactylus leei* Cope. *Ph. tuberculosus* would represent the only lizard not peculiar to the group, and Chatham would be the only island containing two species of the same genus. These specimens need reëxamination.

Snakes.—Snakes are much more widely spread over the islands than is generally believed. They were first mentioned by Dampier. Delano found snakes on Hood; Porter saw "a few small snakes much resembling the common American striped snake" on James, and "a small gray snake" on Albemarle; Steindachner, who distinguishes two varieties, *Dromicus chamissonis dorsalis*, and *D. habeli* records snakes from Indefatigable, Hood, Charles, and Jervis. The "Albatross" collected two snakes, one on James and one on Gardner Island. According to Dr. Habel, snakes are absent from Bindloe and Abingdon. We have, therefore, not less than seven islands on which snakes have been seen. How far the variation in the different islands goes is not yet known.

The Birds.—With the birds we are somewhat better acquainted, due to the collections of Dr. Habel and the "Albatross." The first collection forms the material of Mr. Salvin's extensive memoir on the Avifauna of the Galapagos. The material brought together by the "Albatross" has been very thoroughly worked up by Mr. Robert Ridgway. Collections have been made by Darwin, Kinberg, Dr. Habel, and the "Albatross." A few specimens have also been collected by Dr. W. H. Jones, Kellett and Wood, Dr. Neboux, Cookson and Markham. I give a list of islands with the names of the collectors:

Chatham: Darwin, Kinberg, Jones, Kellett and Wood, "Albatross." Charles: Darwin, Neboux, Kinberg, Jones, Cookson, Markham, "Albatross." Indefatigable: Darwin, Kinberg, Habel. "Albatross." James: Darwin, Kinberg, "Albatross." Bindloe: Habel. Albemarle: Darwin, Cookson, "Albatross." Abingdon: Habel, "Albatross." Duncan: "Albatross." Hood: "Albatross."

We have, therefore, collections from nine islands. So far 69 species of birds have been described, besides the albatross, which is recorded by Delano and Wolf from Hood Island, Thirty-two are found on Indefatigable, 28 on Chatham, 27 on James, 23 on Charles, 18 on Abingdon, 14 on Bindloe, 12 on Hood, 5 on Duncan, and 4 on Albemarle. The great number of Indefatigable is due to the collection of Dr. Habel, who brought not less than 267 skins from this island. Albemarle has hardly been touched. Darwin collected one bird. The "Albatross" remained only five hours at Tagus Cove, and collected four species. There can be no doubt whatever that a very much greater number of birds exist on Albemarle. We know from Wolf that some parts of Albemarle, especially the southern ones, have a well-developed flora (fifty to sixty species of Phanerogams in the lower regions) and there must be also birds.

No collections have been made on Brattle, Barrington, Narborough, Jervis, Tower, Wenman, and Culpepper. The number of genera collected is 40; of these 6 are peculiar to the islands, 8 are found in continental America, and 27 have a wide distribution. Of the 69 species 49 are peculiar to the islands, or 71 per cent. The six peculiar genera are Nesomimus, Certhidea, Geospiza, Cactornis, Camarhynchus, and Creagrus. Nesomimus belongs to the Mimidae; Certhidea to the Cœrebidæ or Honey Creepers; Creagrus to the Laridæ; and the three others to the Fringillidæ or finches.

Creagrus contains a single species, and all the specimens the history of which is absolutely known were taken on Dalrymple Rock, near Chatham Island, a rock 65 feet high,—a most peculiar example of distribution of a single genus.

The genus Nesomimus is represented by five species; one is peculiar to Charles, one to Hood, one to Albemarle, and one to Abingdon; the fifth, *N. melanotis*, is found on the central islands, Charles, Chatham, James, Indefatigable.

Certhidea contains three species; one is peculiar to Hood, one to Abingdon and Bindloe, and the third is again found in the central islands, Chatham, James, Indefatigable.

Geospiza is represented by eleven species, two of which, *G. dubia* and *nebulosa*, are doubtful. Hood has a peculiar species, *G. conirostis* Rigw. *G. magnirostis* has been found on Charles and Chatham; *G. media*, based on a single specimen, comes from Hood; *G. strenua* has been found on the central and northern islands; *G. fortis*, also *G. fulginosa*, are typical for the central islands; *G. parvula* and *dentirostris* seem to be the original inhabitants of Abingdon and Bindloe.

Cactornis shows five species; *C. brevirostis* is only found on Chatham; *C. assimilis* is typical for Bindloe; *C. abingdonii* for Abingdon; *C scandens* and *pallida* spread over the central islands; no form has so far been found on Hood Island.

Camarhynchus is represented by six species; none is known from Hood; two, *C. prosthemelas* and *C. habeli*, are characteristic of the northern Abingdon and Bindloe; *C. townsendi* has only been found on Charles; the other species occur on the central islands.

As a whole we find in the birds the same distribution as in the reptiles, notwithstanding flight could enable them to reach the different islands. The northern islands, Abingdon and Albemarle, show different forms from the central islands. The same is the case with Hood, so far as it has been examined. Some species of the genus Geospiza, which contains the greatest members, have perhaps only lately spread over a greater number of islands than the others. This genus needs further examination. It seems that in the time when Darwin visited the islands the birds were more restricted in distribution. I think it possible to trace the "original" locality of each species of this genus.

If we now compare the results we have reached about the distribution and variation of birds and reptiles, we must admit that we have found absolute harmony.

We find exactly the same in regard to the flora, but unfortunately only five islands of the central group have been examined, and that but little,—Chatham, Charles, James, Indefatigable, and Albemarle. All that we know of the flora of Indefatigable, for instance, was collected in a few hours by Andersson. All these islands reach into the humid region. Great results doubtless will be found when the northern and southern islands have been studied, and also the lower ones of the central group, like Barrington and Duncan, for instance. The peculiar genera found in the Galapagos are represented by peculiar species on the different islands; and the same is true for the non-endemic genera.

(*To be continued.*)